Reservoir Characterization While Drilling - A Real Time Geosteering Answer to Maximize Well Values: A Case Study, Offshore Abu Dhabi*

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Abstract

The Late Jurassic (Kimmeredgian-Tithonian) Reservoir-D represents a 3rd order, regressive carbonate sequence, that has been deposited offshore Abu Dhabi in various environments extending from shelf, through offshore bars to a lagoonal environments with tidal flats, overlain by shoal deposits within the middle and upper layers. The reservoir is showing a wide range of lithofacies and rock types, mudstones at the base, to oolitic grainstones, at the top, depending on the water depth and energy during the deposition, at or below the wave base. The vertically and laterally heterogeneous petrophysical character of Reservoir-D results in a poorer predictability of porosity and permeability distribution and requires careful design of data gathering programs. Better understanding could be achieved via extensive studies incorporating cores and log measurements in vertical and low-angle deviated wellbores.

Oil production started from Reservoir-D, offshore Abu Dhabi in the early 1960's, while Down-Flank Water Injection started in 1973 and Crestal Gas Injection in 1994. The current field development plans of Reservoir-D are based on drilling horizontal and highly deviated wellbores along the layers of Reservoir-D to enhance the injection and production efficiency. Running radioactive-based porosity logging tools with such well architecture is associated with high operation and environmental risks. To reduce this risk we are presenting a case where nuclear magnetic resonance (NMR) as a source-less porosity logging device, run with the conventional resistivity-gamma ray logging while drilling combination achieved effective real-time formation evaluation and supported efficient well placement to maximize the reservoir contact. Insights into the (NMR) real-time log data as a lithology independent porosity logging tool are being discussed with much focus on the added value of the transverse relaxation time (T2) spectrum analysis to characterize the pore size distribution, geosteer the wellbore to track the better quality pores and generate a real-time permeability profile. The formation evaluation, including the NMR log analysis for this highly deviated well, has effectively supported the design of the following Inflow Control Valves (ICV) completion operation for water injection in a timely effective process.

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Kruspe, T., H.F. Thern, G. Kurz, M. Blanz, R. Akkur, S. Ruwaili, D. Seifert, and A.F. Marsala, 2009, Slimhole application of magnetic resonance while drilling: SPWLA, 50th Annual Symposiom.

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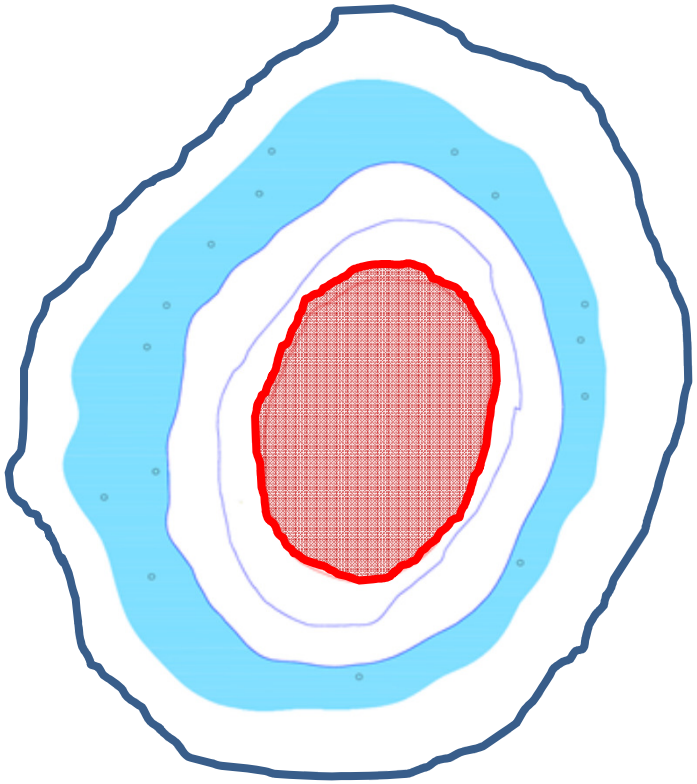
Reservoir Characterization While Drilling; A Real Time Geosteering Answer to Maximize Well Values. A Case study, Offshore Abu Dhabi

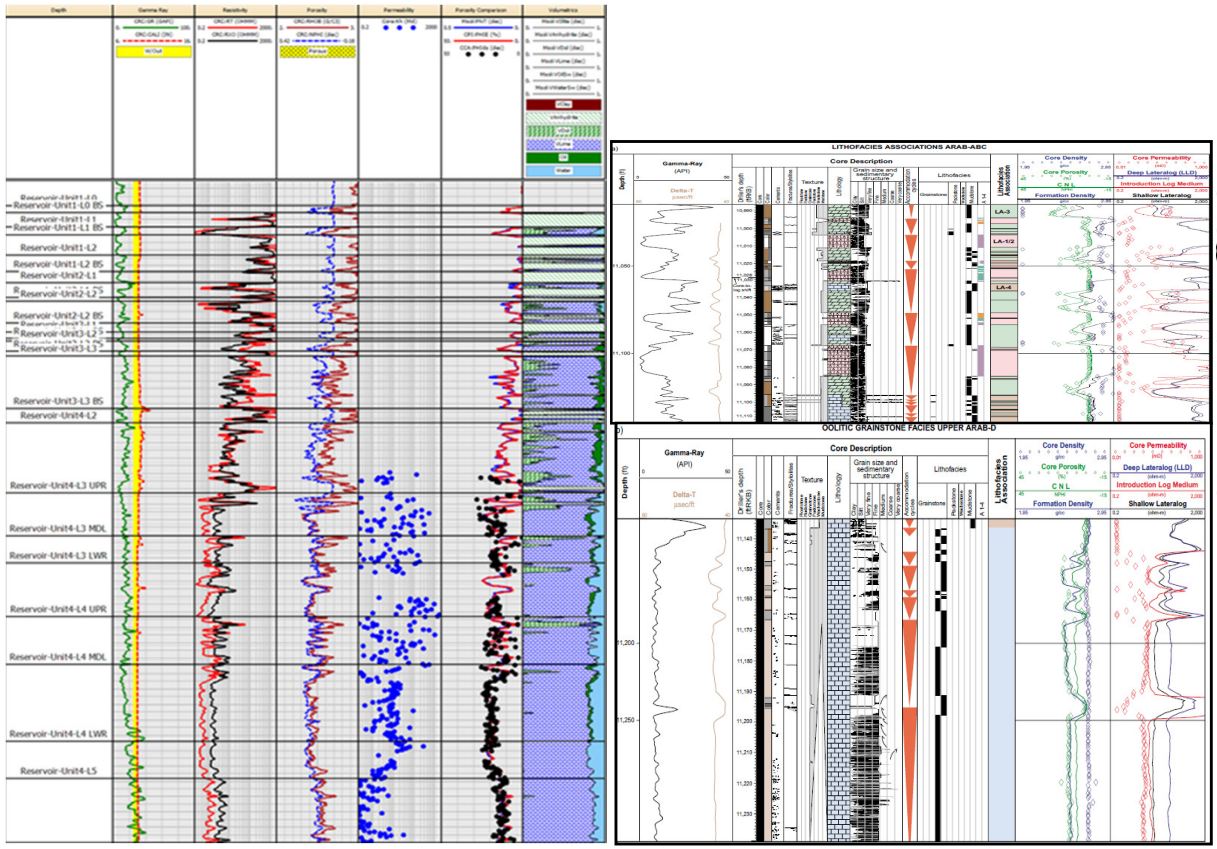
Amr M. Serry (ADMA-OPCO), Ulrich Herz, Larisa Tagarieva (Baker Hughes)

Background: Brief Field History



- Field Discovered 1958 and producing since 1962.
- Down-flank water injection since 1973 (formation water dilution).
- Crestal gas injection for pressure support purposes, since 1994.
- More challenging FE , pay zone identification.
- Heterogeneous, diagenesis controlled pore systems.
- High impact on fluid flow.

Background: The Upper Jurassic Carbonate Reservoirs in the Field



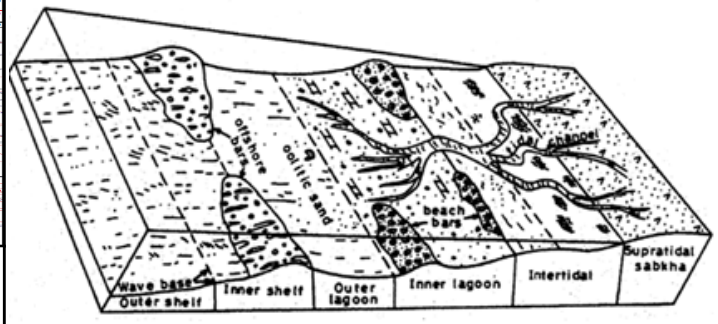
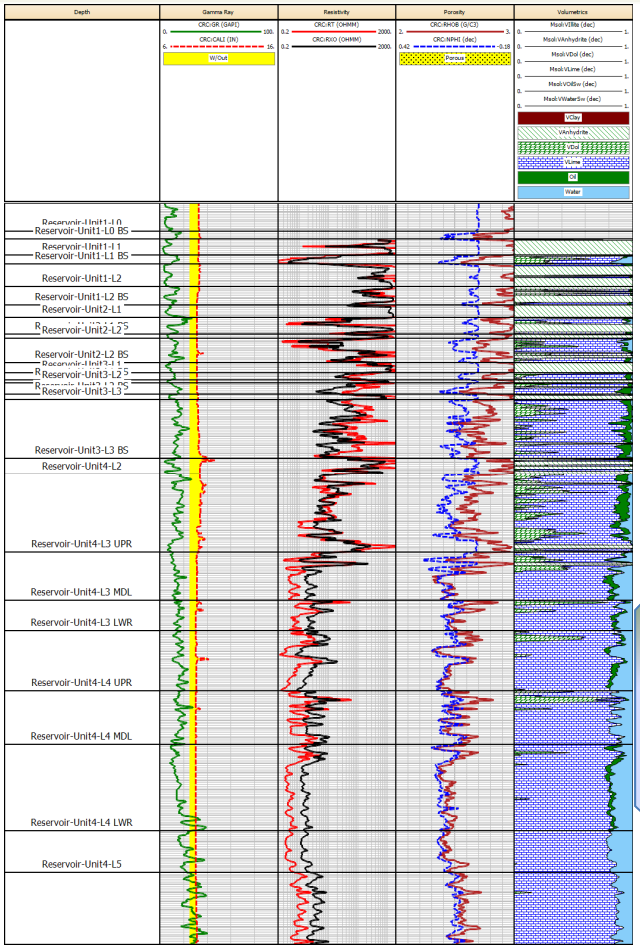


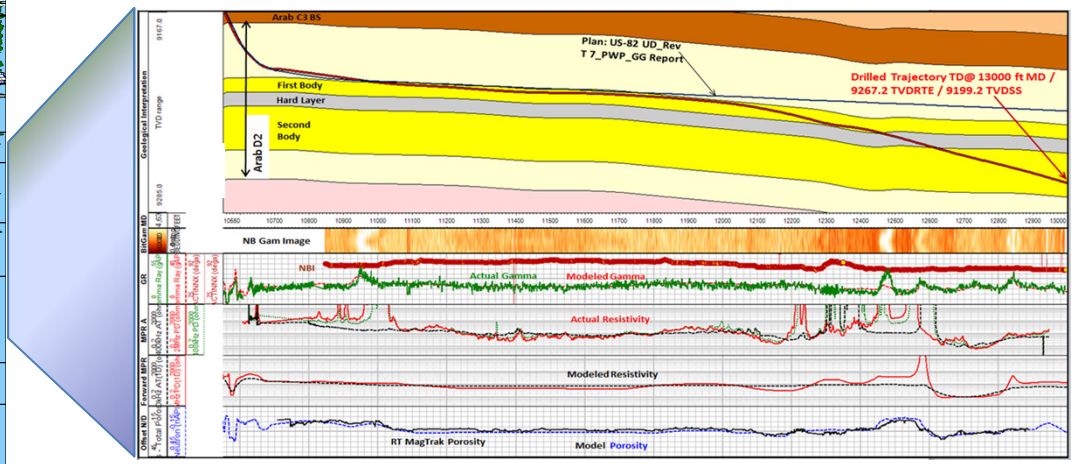
Figure.3. A Constructed Depositional model for the Upper Jurassic in the southern and South-western Arabian Gulf (Alsharhan and Whittle, 1995).

Figure 2: Typical core and log expressions of the Upper jurassic shallowing-upward cycles for the various lithofacies associations, Grötsch et al. (2003)



Well Objectives

- Side-track the original drain well and complete it as a dual water injector.
- Drill a horizontal drain into Reservoir Unit-4 Layer- 02.
- Place another highly deviated 6” water injector drain into Reservoir Unit-4 Layers 3M/L+ Layer 4U/M.
- Expected complex lithology, vertical and lateral heterogeneity.
- Real Time FE for ICD design (Next Rig Operation).
- Honoring the environmental regulations “Sourceless Technology”.



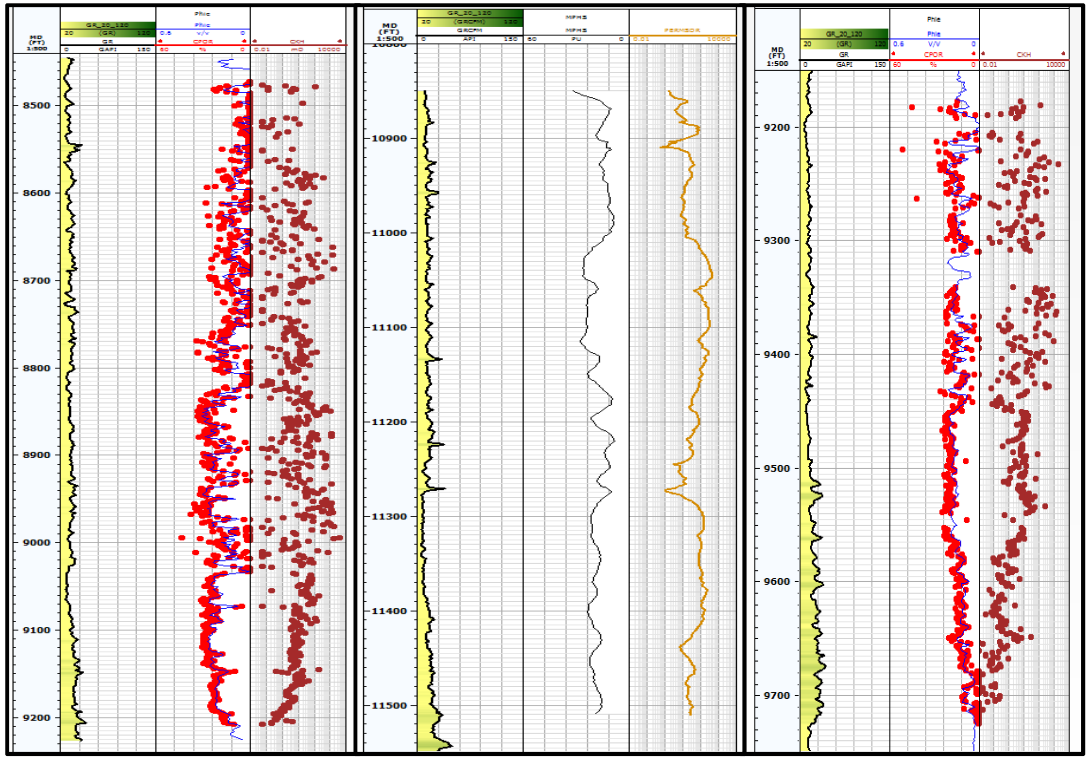
Approach and Methodology: NMR Permeability Models

- Not always simple
  - Especially in Carbonates
  - Would normally require calibration/normalization to permeability from core or mobility from pressure buildup tests.

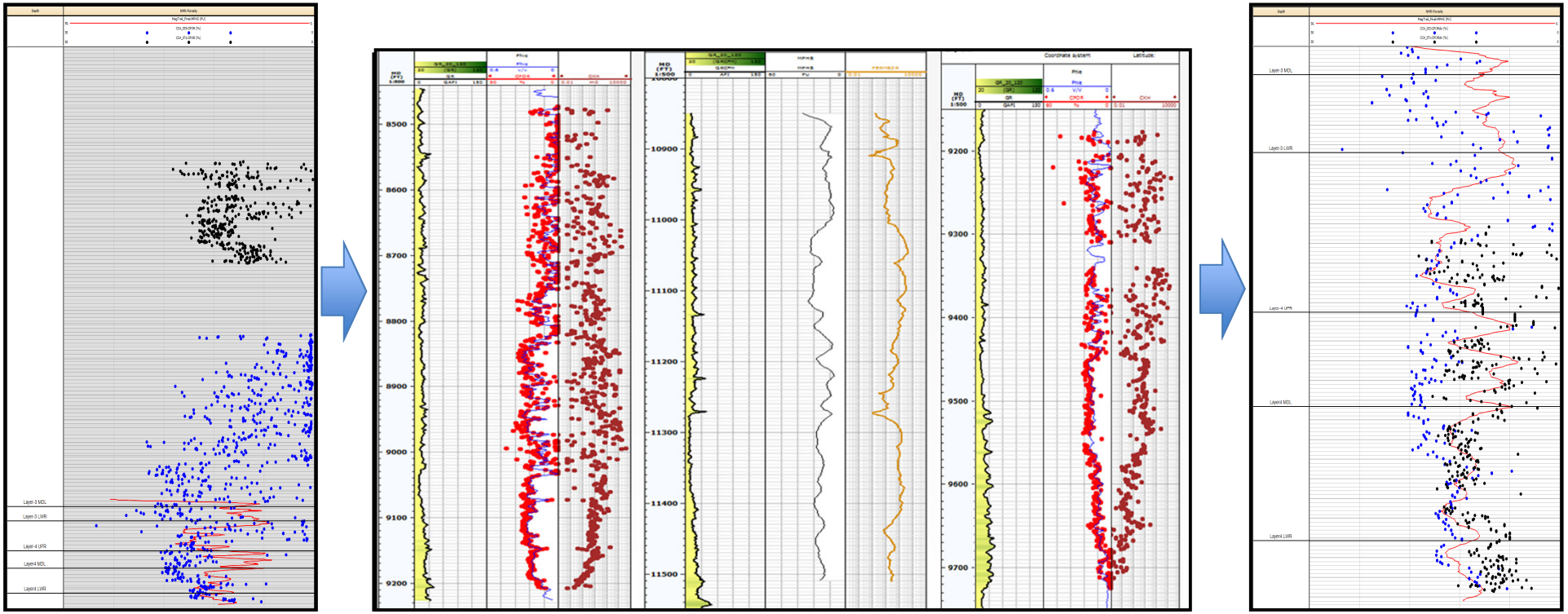
- Neither core nor PT available in this well but core porosity and permeability from offset wells, however no NMR in offset wells.

- Both approaches require log and core data to be on the same depth!

Approach and Methodology: Real time NMR data: Depth Control

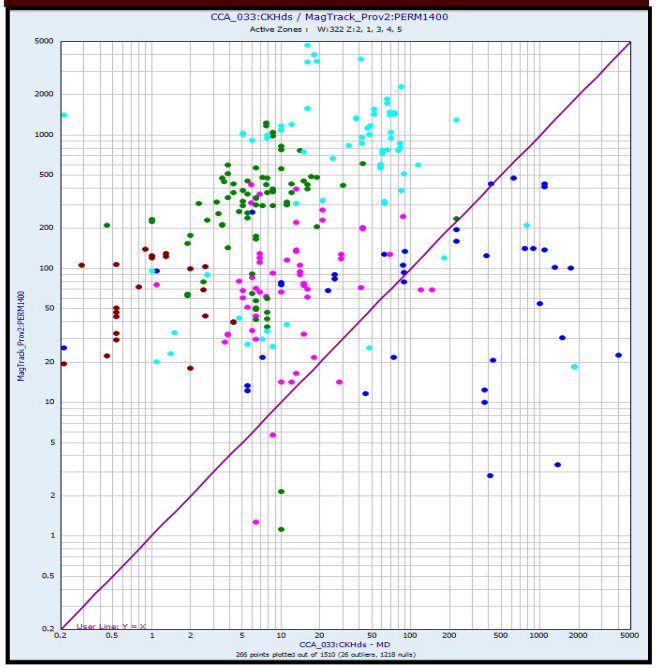


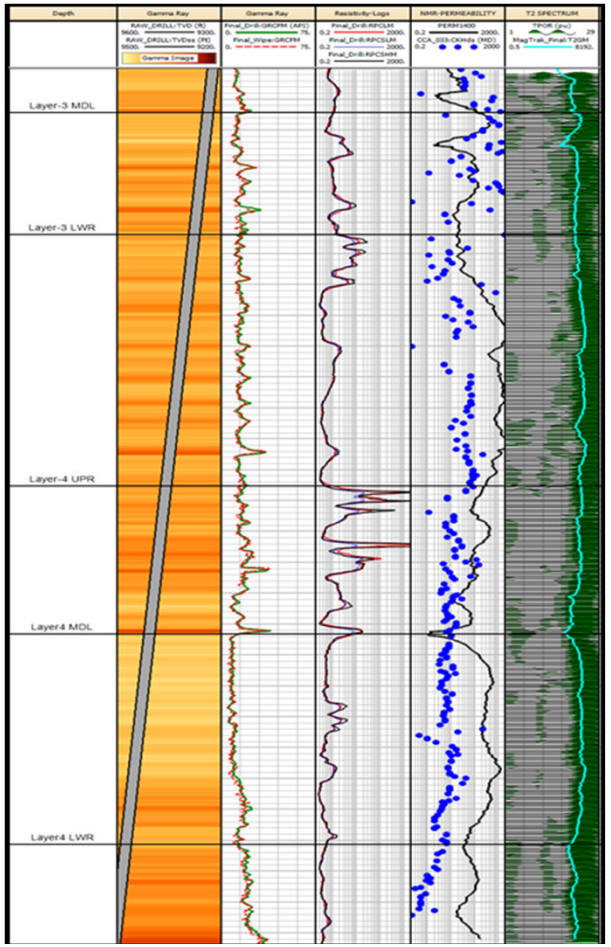
Using Offset Well Core Data



Permeability Correlations: Coates

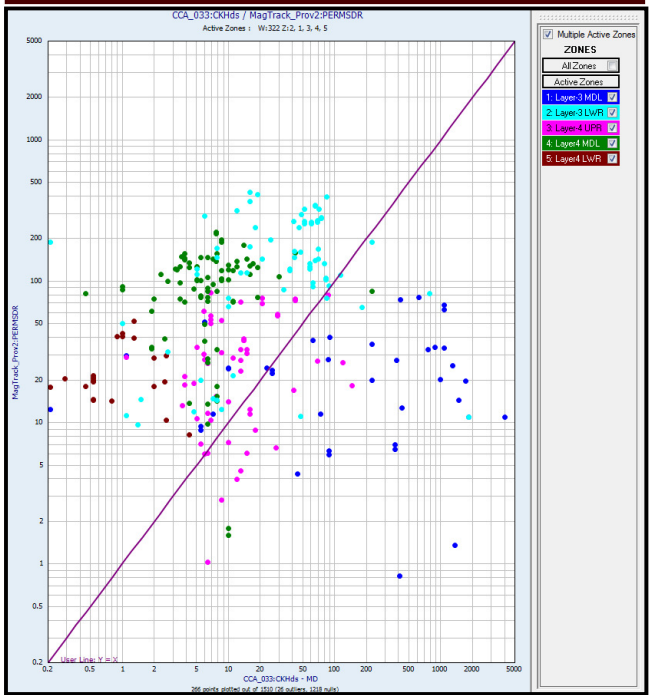
$$k_{Coates} = \left(\frac{\phi}{C}\right)^4 \cdot \left(\frac{BVM}{BVI}\right)^2$$

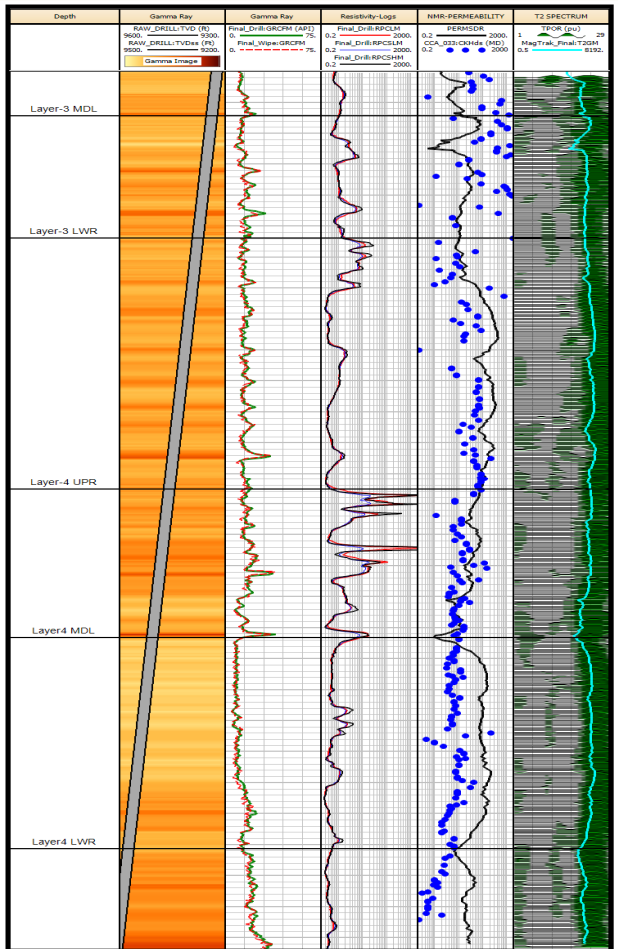




Permeability Correlations: SDR

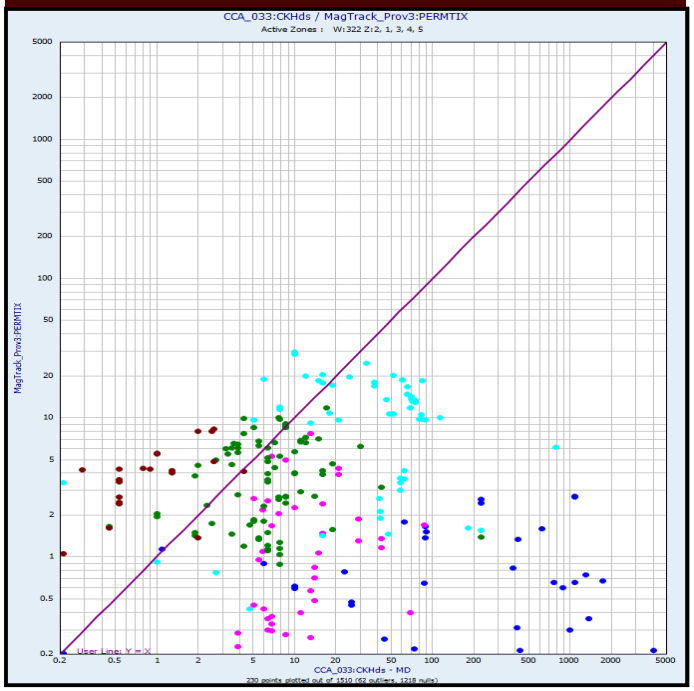
$$k_{T_{2GM}} = c \cdot \phi^4 \cdot T_{2GM}^2$$

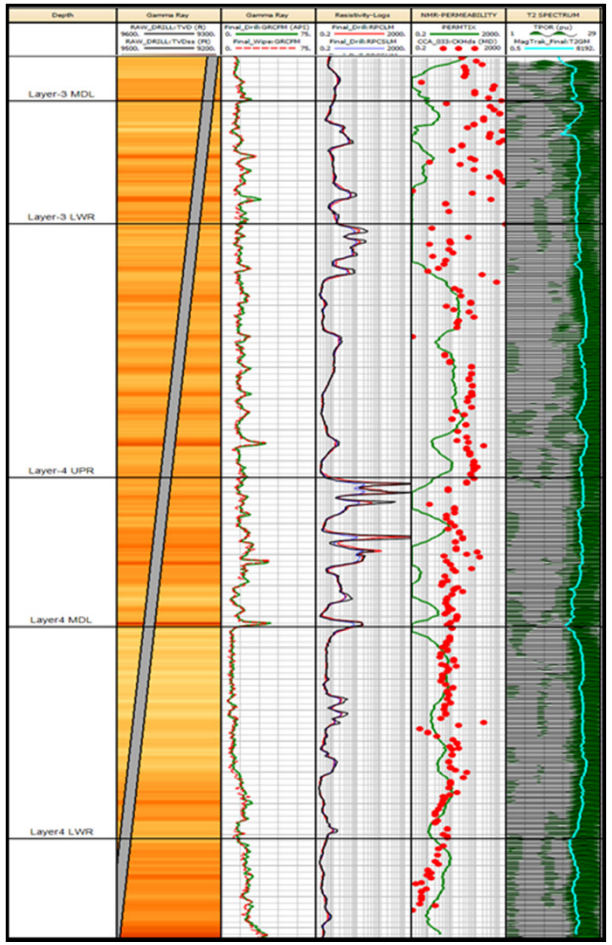




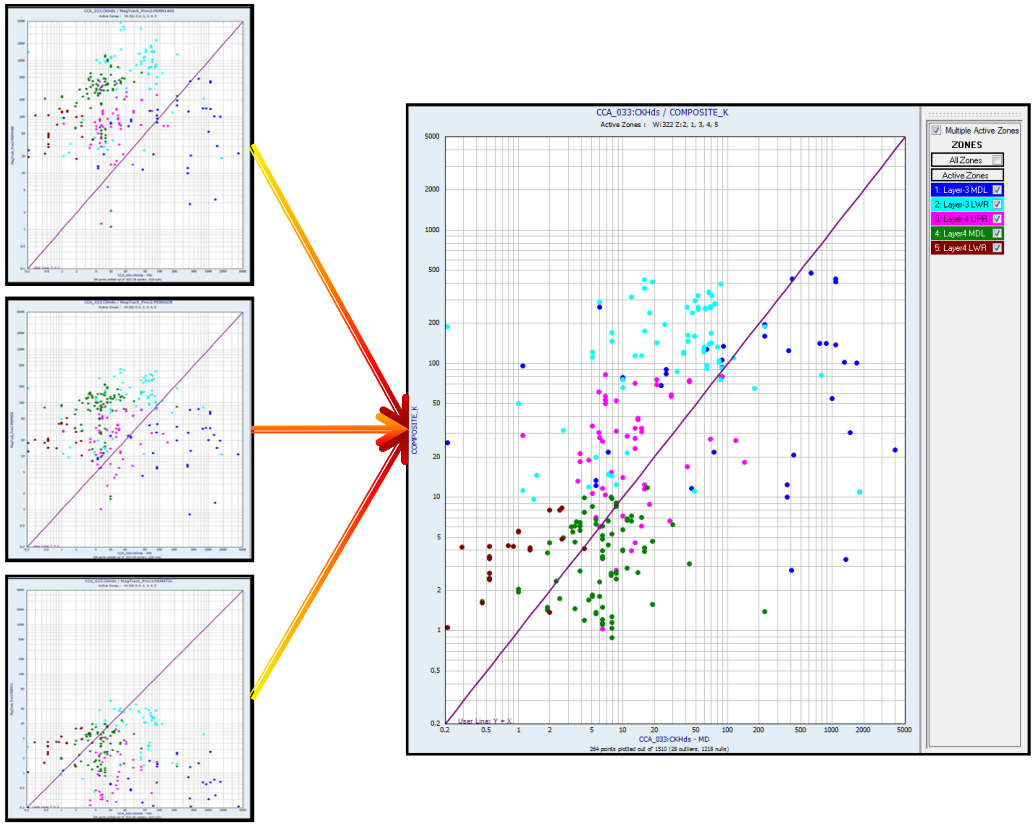
Permeability Correlations: Tixier

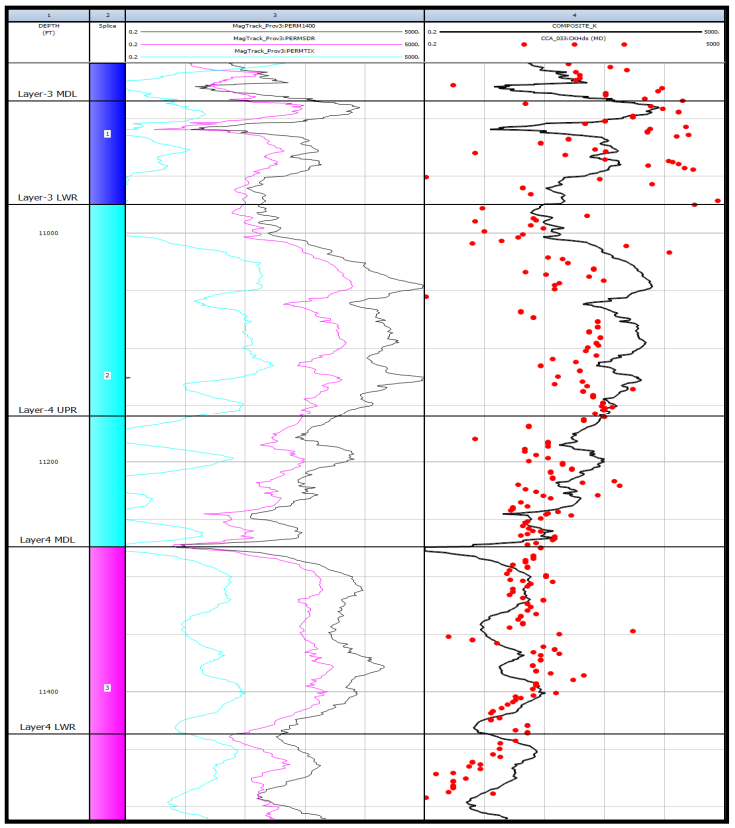
$$K_{tixier}^{1/2} = C.\frac{\Phi^3}{Swirr}$$



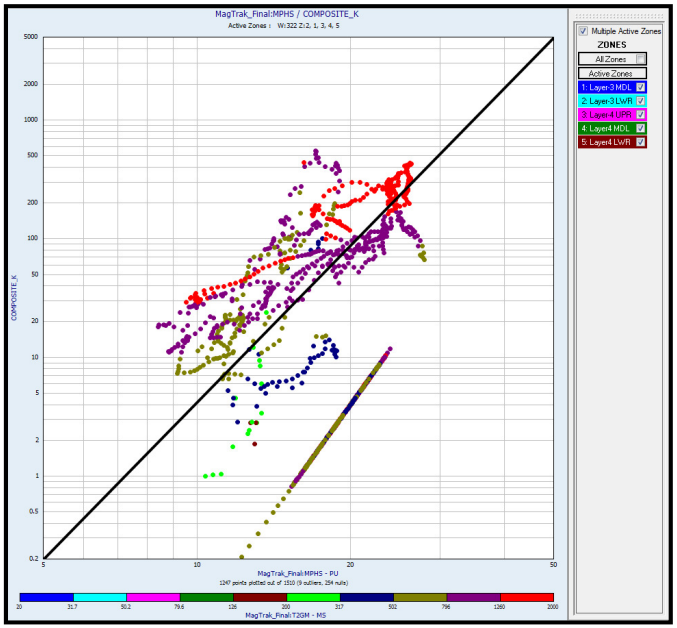


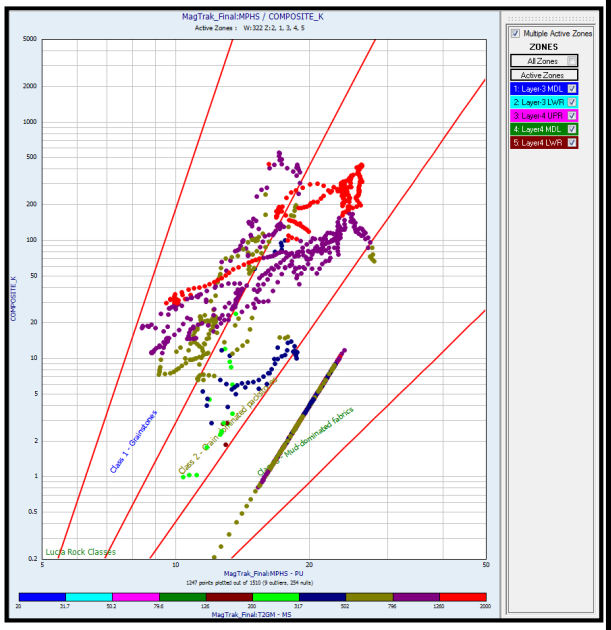
Permeability Correlations: Composite Approach

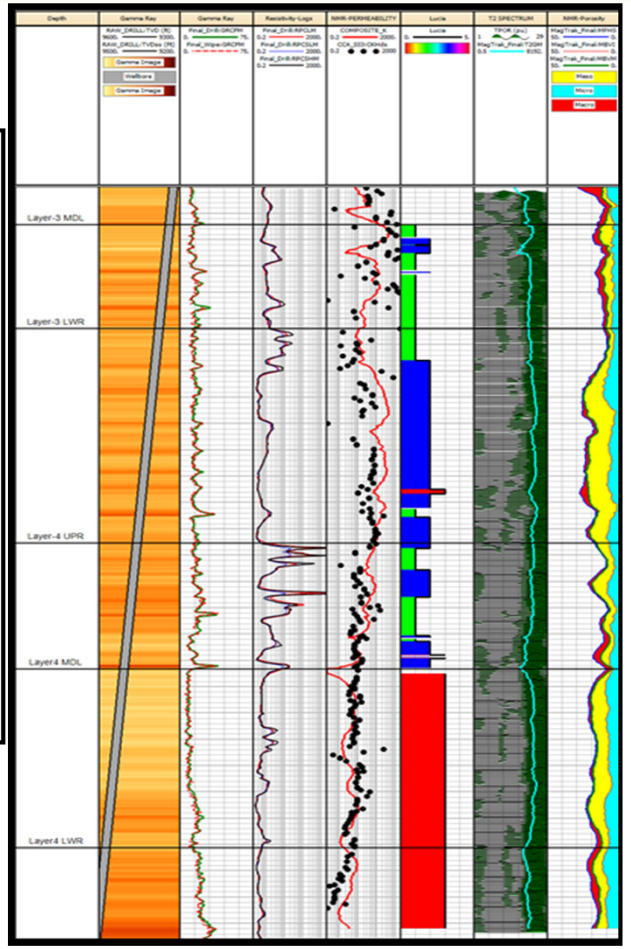




NMR Log Based Characterization







Result and added values

i. Petrophysics driven Well Placement.

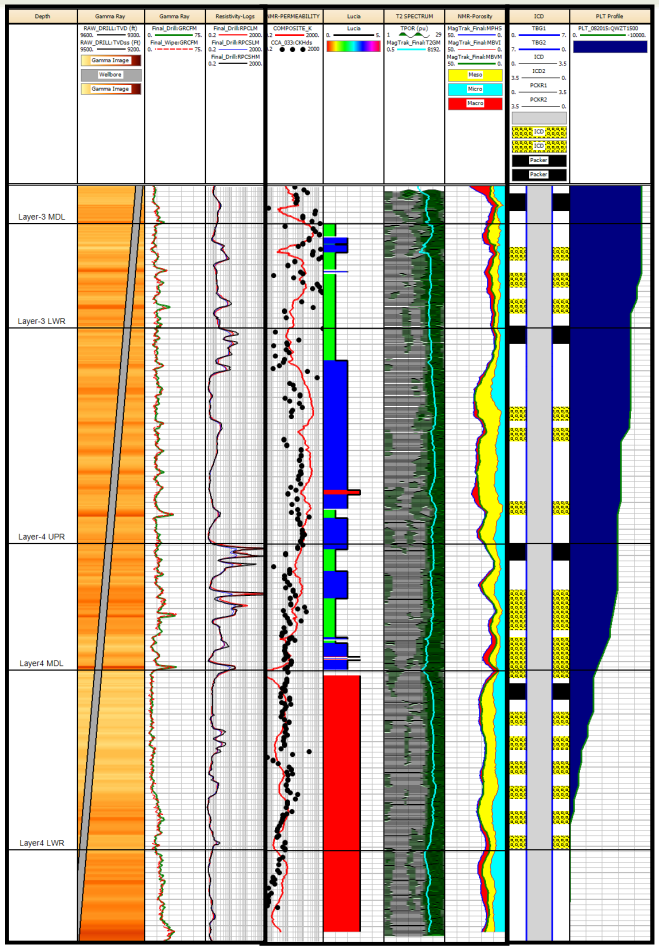
ii. Real-Time Reservoir Characterization:

- *Calibrated Porosity and Permeability profiles.*
- *Reservoir Rock Typing in Heterogeneous Carbonates.*

i. Reliable Productivity profile.

ii. ICD zonation and configuration.

iii. Effective coring alternative (costs/time savings).



Conclusions

- The real time NMR data acquisition provided a lithology independent porosity data in addition to resistivity and Gamma ray, supporting well placement and formation evaluation.
- The relaxation time (T2) spectrum analysis in real time was applied to characterize the pore size distribution (reservoir rock quality).
- A scientifically calibrated permeability to offset well core data was done in a composite approach replacing the manual normalization across the different flow units.
- ICD design was consequently completed based on the permeability profile for water injection, later tested successfully.
- The Established algorithm is applicable to future wells at the same upper jurassic reservoir units in the field.